AGRICULTURE

Project Fact Sheet

Biodegradable Performance Polymers from Switchgrass

Benefits

- Uses a biomass feedstock that will not compete for land with food crops
- Yields a biodegradable performance polymer
- Reduces petroleum used to produce polymers
- Produces power from switchgrass residue after PHA extraction
- Potential 2020 target market is 2.6 billion lb per year
- Projected 2020 total energy savings are 107 trillion Btu per year
- Projected 2020 fossil fuel feedstock displacement is 85.7 trillion Btu per year

Applications

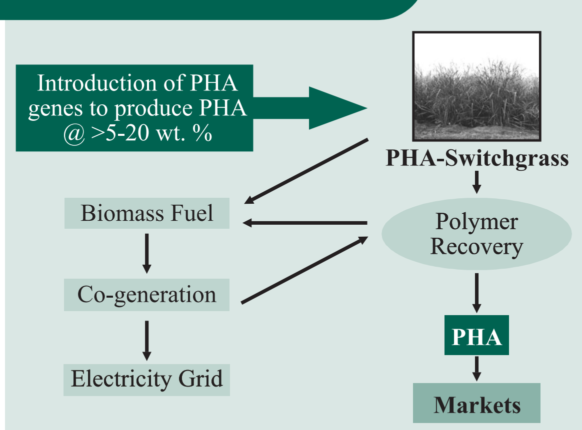
Adding PHAs to energy crops such as switchgrass can help make bioenergy production more economically attractive. The success of this project may also open the door for other "plants as factories."

Polymer and Power to be Obtained from Switchgrass

Polyhydroxyalkanoates (PHAs) are a broad family of polyester polymers, some of which are produced in nature by bacteria as energy storage compounds. ICI and Zeneca developed commercial fermentation technology and introduced some PHA polymers into the marketplace in the late 80's and early 90's. They demonstrated that these polymers can be very useful in a number of applications. A wide range of hydroxy acids can be used in PHAs, resulting in a broad range of polymer properties and performance. The cost of producing PHAs by fermentation limits their use to high value-added applications. If one is able to successfully transfer the genes that produce PHAs from microorganisms to plants and produce PHAs directly in plants at high yields, then the cost of production would be reduced substantially, and PHAs could be cost-competitive with commodity plastics. The feasibility of this has already been shown in some model plant systems. Metabolix, Inc. and its partners plan to build on past research by developing a PHA production system in switchgrass.

Switchgrass is a high yielding, perennial grass native to North America. It can be grown on marginal land and has been used to prevent soil erosion. In 2000, switchgrass was identified in *The Economic Impacts of Bioenergy Crop Production in U.S. Agriculture* as the most suitable target for bioenergy commercialization and much work has been done on maximizing the yield per acre as well as improving other properties. The technology developed by Metabolix, Inc. and its partners takes advantage of switchgrass' agronomic traits while embodying two new concepts: 1) Plants as factories, in which the desired product is produced within the plant, extracted, then blended to achieve consistent and desired properties, and 2) Establishment of a biorefinery, in which products and energy (biofuels such as ethanol or biopower) are created at a single facility.

Figure 1. PHA and Power Production



Genetic engineering will be used to insert the genes encoding PHA-producing enzymes into switchgrass. In addition, a method for gene containment to prevent gene transfer to wild grass species will be evaluated. Biomass remaining after PHA extraction will be burned to generate power.

Project Description

Goal: To demonstrate the production of PHAs in switchgrass, recover the polymers, and capture the energy value of the residual biomass.

The genetic engineering portion of this project is comprised of four tasks. The first task will be to use nuclear transformation to add PHA-producing enzymes into switchgrass. A program has recently been initiated to transfer genes encoding the PHA enzymes to switchgrass. The second task is the plastid transformation of PHA production systems into tobacco which has been attempted before, but without much success. Alternate genes that may be more suitable for plastid transformation have been identified and will be tested. The third task is the development of chemically-inducible plastid encoded PHA production which will address the potential problem of high PHA production affecting plant growth. The last task will be to develop a reproducible plastid transformation protocol for switchgrass. Current plastid transformation technology uses spectinomycin as a selection agent, which switchgrass is naturally resistant to. A newly developed selection system will be adapted for switchgrass and used to introduce the plastid integrated PHA production systems developed in task 2 to switchgrass.

Researchers will develop an efficient process to recover PHAs from switchgrass biomass. The two methods to be tested are: 1) solvent extraction of PHAs from ground-up switchgrass; and 2) degradation of switchgrass using hydrolytic enzymes and subsequent isolation of PHAs from the aqueous stream. In the first method, preference will be given to “green” solvents such as ethanol and ethyl acetate.

The properties and composition of “crude” PHAs recovered from switchgrass may vary by field and by season. The demands of applications may also require variations in PHA copolymer compositions. To address this, physical and reactive blending will be used to create copolymers with compositions held to tight specifications. Physical blending is very well known and widely practiced. Reactive blending has been widely studied as well, but it is usually carried out at temperatures where PHAs decompose. Preliminary studies have identified candidate catalysts for reaction blending of PHAs and these will be tested.

Progress and Milestones

- Nuclear transformation of plastid targeted PHA enzymes into switchgrass
- Development of plastid-encoded PHA production systems
- Development of inducible plastid-encoded PHA production systems
- Introduction of plastid-encoded PHA production systems into switchgrass
- Development of copolymer capability for plant-based PHAs
- Development of optimized recovery processes with solvent extraction
- Life cycle analysis
- Investigation of applications for PHAs

Project Partners

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May 2002